

## **APPENDIX 8.6**

### **Landfill Gas Modeling**

## **Appendix 8.6**

### **LFG Generation Modeling**

LFG generation estimates for the Mission Bay Landfill was developed using the EPA's LFG generation model (LANDGEM, Pelt et al, 1998) and actual methane gas concentrations reported from analytical data collected from the raw LFG samples taken from the Mission Bay Landfill.

Inputs for the EPA model included the estimates of in-place refuse amounts, which were placed during the operational period of the landfill (1952 to 1959), the ultimate methane generation potential ("Lo" value) of 170 m<sup>3</sup>/Mg, and a refuse decay coefficient ("k" value) of 0.05. Refuse data was derived from previous investigations including a site assessment plan prepared for the City of San Diego by Woodward-Clyde Consultants on August 22, 1983, historical data review, as well as information collected by SCS. Default "Lo" and "k" values were derived from the EPA's Compilation of Air Pollutant Emission Factors (AP-42), Section 2.4 on landfills and/or from SCS' own database of factors derived from empirical studies of LFG recovery data of over 300 landfills, including over 75 landfills in Southern California. Landfill gas generation estimates were used in the exposure assessment portion of the health risk assessment. The results of the model indicate that the LFG generation rate for 2005 is 105 cubic feet per minute (cfm). The results of the LFG generation model can be found in Table 8.6.1.

Based on OEHHA comments dated May 14, 2004, detected concentrations of toxic air contaminants (TAC) in Summa canisters were multiplied by the number of composite samples taken into each canister. This is based on the possibility that all contaminants in the composite sample were collected from a single location, and were diluted with sample from other locations that had no detectable contaminants. Resulting concentrations of TAC in landfill gas are shown in Table 8.6.2. Total estimated LFG emissions were calculated in tons/year (tons per year) assuming a landfill gas total flow from the landfill of 105 cfm and a methane content of 50%. Total estimated LFG emissions are also shown on Table 8.6.2.

Maximum surface emissions of the landfill were then estimated using the total estimated LFG emissions, assuming a landfill surface area of 115 acres. Maximum surface emissions from the landfill site are presented on Table 8.6.3. The resulting maximum surface emissions were then used in a "box model" to determine on-site airborne concentrations of LFG.

### Calculation of On-Site Airborne Concentrations of LFG (LFG EPC)

To calculate on-site airborne concentrations of LFG, a “box” model was utilized as recommended by the California Air Resources Board (DaMassa, 1992). A box model is a simple mass-balance equation that uses the concept of a theoretically enclosed space (i.e., box) over the impacted area. The model assumes that emissions of contaminants into a box, with their removal based on wind speed.

Airborne concentrations of LFG within the box were calculated and used as on-site EPCs for contaminant concentrations for on-site receptors. The LFG EPC calculated within the box is calculated by the following equation:

$$B = QA/(u)(h)(l) \times CF$$

Where:

B	=	Box concentration, EPC (ug/m <sup>3</sup> )
Q	=	Emission flux (g/cm <sup>2</sup> -sec)
A	=	Emitting area of the site (cm <sup>2</sup> )
u	=	Wind speed (cm <sup>2</sup> /sec)
h	=	Height of box (cm)
l	=	Length of box (cm)
CF	=	Conversion factor, 10 <sup>12</sup> (ug-cm <sup>3</sup> /g-m <sup>3</sup> )

The results of the box model calculations are presented in Table 8.6.4.

**TABLE 8.6.1.**  
**LANDFILL GAS GENERATION MODEL**  
**PROJECTED LFG AND NMOC GENERATION RATES**  
**MISSION BAY LANDFILL, SAN DIEGO, CALIFORNIA**

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	Disposal Rate (Mg/yr)	Refuse In-Place (Mg)	Methane Generation Rates (m <sup>3</sup> /yr)	LFG Generation Rates (cfm) (Million ft <sup>3</sup> /yr)	NMOC Generation Rates (tons/yr)	NMOC Generation Rates (Mg/yr)
1952	75,000	0	68,039	0	0.000E+00	0	0	0
1953	150,000	75,000	136,078	68,039	5.783E+05	78	41	18
1954	150,000	225,000	136,078	204,117	1.707E+06	229	121	53
1955	150,000	375,000	136,078	340,194	2.780E+06	374	196	86
1956	150,000	525,000	136,078	476,272	3.801E+06	511	268	118
1957	150,000	675,000	136,078	612,350	4.773E+06	641	337	148
1958	150,000	825,000	136,078	748,427	5.696E+06	765	402	177
1959	150,000	975,000	136,078	884,505	6.575E+06	884	464	204
1960	0	1,125,000	0	1,020,583	7.411E+06	996	523	230
1961	0	1,125,000	0	1,020,583	7.050E+06	947	498	219
1962	0	1,125,000	0	1,020,583	6.706E+06	901	474	208
1963	0	1,125,000	0	1,020,583	6.379E+06	857	451	198
1964	0	1,125,000	0	1,020,583	6.068E+06	815	429	189
1965	0	1,125,000	0	1,020,583	5.772E+06	776	408	179
1966	0	1,125,000	0	1,020,583	5.490E+06	738	388	171
1967	0	1,125,000	0	1,020,583	5.223E+06	702	369	162
1968	0	1,125,000	0	1,020,583	4.968E+06	668	351	154
1969	0	1,125,000	0	1,020,583	4.726E+06	635	334	147
1970	0	1,125,000	0	1,020,583	4.495E+06	604	317	140
1971	0	1,125,000	0	1,020,583	4.276E+06	575	302	133
1972	0	1,125,000	0	1,020,583	4.067E+06	547	287	126
1973	0	1,125,000	0	1,020,583	3.869E+06	520	273	120
1974	0	1,125,000	0	1,020,583	3.680E+06	495	260	114
1975	0	1,125,000	0	1,020,583	3.501E+06	470	247	109
1976	0	1,125,000	0	1,020,583	3.330E+06	447	235	104
1977	0	1,125,000	0	1,020,583	3.168E+06	426	224	98
1978	0	1,125,000	0	1,020,583	3.013E+06	405	213	94
1979	0	1,125,000	0	1,020,583	2.866E+06	385	202	89
1980	0	1,125,000	0	1,020,583	2.726E+06	366	193	85
1981	0	1,125,000	0	1,020,583	2.593E+06	349	183	81
1982	0	1,125,000	0	1,020,583	2.467E+06	332	174	77
1983	0	1,125,000	0	1,020,583	2.347E+06	315	166	73
1984	0	1,125,000	0	1,020,583	2.232E+06	300	158	69
1985	0	1,125,000	0	1,020,583	2.123E+06	285	150	66
1986	0	1,125,000	0	1,020,583	2.020E+06	271	143	63
1987	0	1,125,000	0	1,020,583	1.921E+06	258	136	60
1988	0	1,125,000	0	1,020,583	1.828E+06	246	129	57
1989	0	1,125,000	0	1,020,583	1.738E+06	234	123	54
1990	0	1,125,000	0	1,020,583	1.654E+06	222	117	51
1991	0	1,125,000	0	1,020,583	1.573E+06	211	111	49
1992	0	1,125,000	0	1,020,583	1.496E+06	201	106	47
1993	0	1,125,000	0	1,020,583	1.423E+06	191	101	44
1994	0	1,125,000	0	1,020,583	1.354E+06	182	96	42
1995	0	1,125,000	0	1,020,583	1.288E+06	173	91	40
1996	0	1,125,000	0	1,020,583	1.225E+06	165	87	38
1997	0	1,125,000	0	1,020,583	1.165E+06	157	82	36
1998	0	1,125,000	0	1,020,583	1.108E+06	149	78	34
1999	0	1,125,000	0	1,020,583	1.054E+06	142	74	33
2000	0	1,125,000	0	1,020,583	1.003E+06	135	71	31
2001	0	1,125,000	0	1,020,583	9.541E+05	128	67	30
2002	0	1,125,000	0	1,020,583	9.076E+05	122	64	28
2003	0	1,125,000	0	1,020,583	8.633E+05	116	61	27
2004	0	1,125,000	0	1,020,583	8.212E+05	110	58	26
2005	0	1,125,000	0	1,020,583	7.811E+05	105	55	24
2006	0	1,125,000	0	1,020,583	7.430E+05	100	52	23
2007	0	1,125,000	0	1,020,583	7.068E+05	95	50	22
2008	0	1,125,000	0	1,020,583	6.723E+05	90	47	21
2009	0	1,125,000	0	1,020,583	6.395E+05	86	45	20
2010	0	1,125,000	0	1,020,583	6.084E+05	82	43	19
2011	0	1,125,000	0	1,020,583	5.787E+05	78	41	18
2012	0	1,125,000	0	1,020,583	5.505E+05	74	39	17

ESTIMATED NMOC CONCENTRATION IN LFG: 4000 ppmv  
 ASSUMED METHANE CONTENT OF LFG: 50%  
 SELECTED DECAY RATE CONSTANT: 0.05  
 SELECTED ULTIMATE METHANE RECOVERY RATE: 5,446 ft<sup>3</sup>/ton  
 METRIC EQUIVALENT: 170 cu m/Mg

**TABLE 8.6.2.**  
**EMISSIONS FROM LANDFILL GAS**  
**MISSION BAY LANDFILL**  
**SEA WORLD DRIVE**  
**SAN DIEGO, CALIFORNIA**

Toxic Air Contaminant (TAC) <sup>1</sup>	Molecular Weight	Concentration of TAC Found in LFG <sup>2</sup>	Total Estimated LFG Emissions <sup>3</sup>
	g/Mol	ppmv	tons/yr
Hydrogen sulfide	34.1	100	0.244341
Total Non-Methane Hydrocarbons as Methane	16.0	4600	5.286927
1,2-Dichlorobenzene	147.0	0.145	0.001527
1,4-Dichlorobenzene	147.0	0.8	0.008427
2-Butanone (MEK)	72.1	0.2	0.001033
Acetone	58.1	0.6	0.002498
Chlorobenzene	112.6	0.18	0.001452
Chlorodifluoromethane	86.5	1.15	0.007128
Chloroethane (Ethyl Chloride)	64.5	0.043	0.000196
Dichlorodifluoromethane (Freon 12)	120.9	0.95	0.008230
Dichlorofluoromethane (Freon 21)	102.9	0.055	0.000406
Ethylbenzene	106.2	4.05	0.030819
n-Butane	58.1	24	0.099949
n-Hexane	86.2	2.35	0.014515
Pentane	72.1	7.5	0.038747
Propane	44.1	55	0.173758
Trichloroethene	131.4	0.0455	0.000428
Vinyl chloride	62.5	0.30	0.001344
Total Xylenes	106.2	0.73	0.005553
<b>TOTAL</b>		<b>4,798</b>	<b>5.6829</b>

**NOTES:**

- (1) Toxic air contaminants include volatile organic compounds identified from TO-15 analysis of landfill gas samples collected from Mission Bay Landfill
- (2) Concentrations are taken from samples collected from Mission Bay Landfill. Based on OEHHA comments (May, 14, 2005), highest concentration of each detected contaminant should be multiplied by the number of composite landfill gas samples (5 samples).
- (3) Based on concentrations of TAC found in LFG and an estimated LFG generation rate of 105 cfm (see Table 1).

**INPUT MODEL VARIABLES**

Landfill Gas Total Flow from LF (See Table C-1, 2005): 105 cfm  
Methane content of LFG 50%

**TABLE 8.6.3.**  
**MAXIMUM SURFACE EMISSIONS FROM SITE**  
**MISSION BAY LANDFILL**  
**SEA WORLD DRIVE**  
**SAN DIEGO, CALIFORNIA**

Toxic Air Contaminants (TAC) <sup>1</sup>	Existing Surface Emissions from Site <sup>2</sup>	Maximum Surface Emissions from Site <sup>3</sup>		Maximum Surface Emissions from Site <sup>4</sup>	
	lb/year		tons/yr	g/sec	g/cm <sup>2</sup> -sec of landfill surface
Hydrogen sulfide	489	489	0.244341	7.03E-03	1.51E-12
Total Non-Methane Hydrocarbons as Methane	10,574	10,574	5.28693	1.52E-01	3.27E-11
1,2-Dichlorobenzene	3.1	3.1	0.00153	4.39E-05	9.44E-15
1,4-Dichlorobenzene	16.9	16.85	0.00843	2.42E-04	5.21E-14
2-Butanone (Methyl Ethyl Ketone)	2.1	2.1	0.00103	2.97E-05	6.39E-15
Acetone	5.0	5.0	0.00250	7.19E-05	1.54E-14
Chlorobenzene	2.9	2.9	0.00145	4.18E-05	8.98E-15
Chlorodifluoromethane	14.3	14.3	0.00713	2.05E-04	4.41E-14
Chloroethane (Ethyl Chloride)	0.4	0.393	0.00020	5.65E-06	1.21E-15
Dichlorodifluoromethane (Freon 12)	16.5	16.5	0.00823	2.37E-04	5.09E-14
Dichlorofluoromethane (Freon 21)	0.8	0.8	0.00041	1.17E-05	2.51E-15
Ethylbenzene	61.6	61.6	0.03082	8.87E-04	1.91E-13
n-Butane	200	200	0.09995	2.88E-03	6.18E-13
n-Hexane	29	29	0.01451	4.18E-04	8.97E-14
Pentane	77.5	77.5	0.03875	1.11E-03	2.40E-13
Propane	348	348	0.17376	5.00E-03	1.07E-12
Trichloroethene	0.86	0.86	0.00043	1.23E-05	2.65E-15
Vinyl chloride	2.7	2.7	0.00134	3.86E-05	8.30E-15
Xylenes	11.1	11.1	0.00555	1.60E-04	3.43E-14

**NOTES:**

(1) Toxic air contaminants include volatile organic compounds identified from TO-15 analysis of landfill gas samples collected from Mission Bay Landfill.

(2) Current surface emission levels (See Table C-2, Total Estimated LFG Emissions).

(3) Converted using factors listed below.

Conversion factors:

Landfill surface area = 115 acres  
= 5,009,400 ft<sup>2</sup>  
= 465,373 m<sup>2</sup>  
since: 1 acre = 43,560 ft<sup>2</sup>  
and 1 ft<sup>2</sup> = 0.0929 m<sup>2</sup>

1 g = 1E-06 metric tons  
1 metric ton = 1.1023 short tons  
1 year = 31,536,000 seconds

**TABLE 8.6.4.**  
**COMPUTATIONS FOR LANDFILL GAS (BOX MODEL)**  
**MISSION BAY LANDFILL**  
**SEA WORLD DRIVE**  
**SAN DIEGO, CALIFORNIA**

Chemical	Emission Flux	Emitting Area <sup>1</sup>	Wind Speed <sup>2</sup>	Box Height <sup>3</sup>	Length of Site <sup>1</sup>	Conversion Factor	On-Site Concentration
	g/cm <sup>2</sup> -sec	cm <sup>2</sup>	cm/s	cm	cm	µg-cm <sup>3</sup> /g-m <sup>3</sup>	µg/m <sup>3</sup>
<b>VOCs</b>							
Hydrogen sulfide	1.51E-12	4.52E+09	313	150	153,924	1.00E+12	9.45E-01
Total Non-Methane Hydrocarbons as Methane	3.27E-11	4.52E+09	313	150	153,924	1.00E+12	2.04E+01
1,2-Dichlorobenzene	9.44E-15	4.52E+09	313	150	153,924	1.00E+12	5.90E-03
1,4-Dichlorobenzene	5.21E-14	4.52E+09	313	150	153,924	1.00E+12	3.26E-02
2-Butanone (Methyl Ethyl Ketone)	6.39E-15	4.52E+09	313	150	153,924	1.00E+12	3.99E-03
Acetone	1.54E-14	4.52E+09	313	150	153,924	1.00E+12	9.66E-03
Chlorobenzene	8.98E-15	4.52E+09	313	150	153,924	1.00E+12	5.61E-03
Chlorodifluoromethane	4.41E-14	4.52E+09	313	150	153,924	1.00E+12	2.76E-02
Chloroethane (Ethyl Chloride)	1.21E-15	4.52E+09	313	150	153,924	1.00E+12	7.59E-04
Dichlorodifluoromethane (Freon 12)	5.09E-14	4.52E+09	313	150	153,924	1.00E+12	3.18E-02
Dichlorofluoromethane (Freon 21)	2.51E-15	4.52E+09	313	150	153,924	1.00E+12	1.57E-03
Ethylbenzene	1.91E-13	4.52E+09	313	150	153,924	1.00E+12	1.19E-01
n-Butane	6.18E-13	4.52E+09	313	150	153,924	1.00E+12	3.86E-01
n-Hexane	8.97E-14	4.52E+09	313	150	153,924	1.00E+12	5.61E-02
Pentane	2.40E-13	4.52E+09	313	150	153,924	1.00E+12	1.50E-01
Propane	1.07E-12	4.52E+09	313	150	153,924	1.00E+12	6.72E-01
Trichloroethene	2.65E-15	4.52E+09	313	150	153,924	1.00E+12	1.66E-03
Vinyl chloride	8.30E-15	4.52E+09	313	150	153,924	1.00E+12	5.19E-03
Xylenes	3.43E-14	4.52E+09	313	150	153,924	1.00E+12	2.15E-02

**Notes:**

<sup>1</sup> Emitting Area (Dimensions) of the site are estimated from Figure 2.1 from Review Draft Workplan for Mission Bay Landfill Site Assessment (SCS, 200

<sup>2</sup> Wind speed is average reported by National Oceanic and Atmospheric Administration (NOAA) for San Diego, California (7 miles per hour [mph]).

<sup>3</sup> The height at which the nose and mouth of the average person are located.